

Wisconsin Highway Research Program

Longitudinal Cracking in Widened Portland Cement Concrete Pavements

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**University of Wisconsin – Platteville
February 28, 2011**

Summary Page

Project Title: Longitudinal Cracking in Widened Portland Cement Concrete Pavements

Proposing Agency: University of Wisconsin – Platteville

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Total Contract Amount: \$50,000

Indirect Cost Portion at 16%

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4. Research Plan

Background

Since approximately the early 1990's, the Wisconsin Department of Transportation (WisDOT) has constructed widened concrete pavements with widths of 26 feet for a rural four-lane divided and 30 feet for a rural two-lane highway. For rural four-lane divided highways, the standard pavement section includes the outside lane paved at 14 feet wide. The reasoning behind use of these sections on mainline paving was to reduce the amount of stress and deflection at the pavement edge of the concrete slabs due to tires running near the edge. Subsequent field evaluation found that extension of the additional 2-3 feet paved beyond the normal traffic path was successful in meeting the intended objective. Based on this evaluation, it was assumed that the widened sections would result in additional service life of the concrete pavement and significantly reduce shoulder maintenance. The revised section was also attractive from a safety standpoint because it eliminated the hazard of edge drop off at the edge of the 12-foot lane.

At the present time, WisDOT has very little information on which to base the performance evaluation of widened PCC pavements. Past studies performed by other researchers have focused on design and construction practices to minimize edge stresses and deflections and consequently reduce shoulder maintenance cost. A broader perspective is needed to allow the performance of concrete pavement width alternatives to be evaluated for cost effectiveness. This is only possible through a thorough investigation of all concrete width alternatives, including those that have been employed in other states and in Wisconsin, as well as an analysis of their cost effectiveness and applicability for Wisconsin.

Many of these pavements are approaching 20 years of service life and some are experiencing longitudinal cracking in the slabs. Qualitatively, it appears that while the current pavement section was a success in reducing edge cracking and shoulder maintenance, it may have made the pavement more susceptible to other forms of distress. The department is commissioning a research study to evaluate the performance of these pavements to determine if there has been an increase in longitudinal cracking in concrete pavement due to the use of wider concrete slabs (14 feet or greater).

The work contained in this research is significant since it will help guide WisDOT, and possibly other highway agencies, with a scientific understanding of the relationships between the performance and costs of concrete pavement width alternatives. Such an understanding will enable WisDOT to validate concrete pavement cross-section design, construction and maintenance practices and better predict concrete pavement performance. In addition, it will provide justification for WisDOT concrete pavement width selection procedures and designs based on life-cycle costs.

Research Objectives

The objectives of this investigation are twofold:

- a. Evaluate and statistically compare the performance of concrete pavements with wider panels (14 feet wide or greater) to the performance of concrete pavements with standard width panels (12 to 13 feet).
- b. Determine the maximum allowable pavement width as a function of pavement thickness in order to achieve optimal concrete pavement performance.

Research Approach

The project objectives will be accomplished through the following series of tasks:

Task 1 - Literature Review

The objective of Task 1 is to identify, collect, review, and synthesize literature and research on criteria for selecting concrete pavement cross-section, indicators used for concrete pavement performance with a focus on longitudinal cracking and influential factors, maintenance cost and practices utilized by states to address longitudinal cracking, as well as recommended practices by national trade associations and professional organizations dealing with concrete pavement products. Online resources for the literature search will include the National Transportation Library (NTL), the Online Computer Library Center's (OCLC) WorldCat, Google, and TRID. TRID is the newly integrated database that combines the records from TRB's Transportation Research Information Services (TRIS) Database and the Organization for Economic Co-operation and Development's (OECD) Joint Transport Research Centre's International Transport Research Documentation (ITRD) Database. TRID provides access to over 900,000 records of transportation research worldwide.

A preliminary search using these online tools indicate that longitudinal cracking on concrete pavements in Wisconsin had been studied as far back as the 1930s (Janda 1935). Excessive longitudinal cracking was observed on STH 13 in Clark and Taylor Counties on both sides of the center parting strip at 2.5 feet to 4.2 feet from the centerline of the pavement. The pavement consisted of a variable thickness cross-section (9" - 6.5" - 9") with a total width of 20 feet. Tie bars at the center joint were placed at 2- or 4-foot centers. The study showed that much of the cracking occurred at locations with Colby silt loam soil, which is prone to frost heaving. It was concluded that the combination of tie bar stiffening of the center section of the pavement and the irregular heaving resulted in the longitudinal cracking at a short distance from the ends of the bar.

Ardani et al. (2003) evaluated premature longitudinal cracking on concrete pavements in Colorado along IH-70 and USH-287. Results from visual observations and field and lab investigations revealed that the premature longitudinal cracking was attributed to a combination of factors including untreated native soil with high swelling potential, poor compaction, shallow saw-cut at the shoulder joints, and malfunctioning or improper paver vibrators. The study further concluded that 14-ft-wide slabs did not contribute to longitudinal cracking occurrence. Hence, the study highly recommended using the 14-ft slab design on rural highways.

The Ohio Department of Transportation (ODOT) ramp standards dictate concrete panel width of 16 feet with 6-foot right side and 3-foot left side shoulders with cross slope breaks at the shoulders. Survey responses from 12 Ohio districts revealed that 5 districts experienced longitudinal cracking in the 16-foot wide ramps. After examining practices in other states, ODOT recommended alternative panel width of 8 foot and 12-1/2 foot for curtailing longitudinal cracking (ODOT 2003).

Task 2 - Development of Experimental Plan for Evaluation of Concrete Pavement Performance

The experimental plan will use findings from the literature review as a potential guide in determining pavement characteristics critical to the performance of pavements. A series of four subtasks has been designated to better manage this project.

Subtask 2.1 - Data Sources

The objective of Subtask 2.1 is to identify and review concrete pavement projects constructed in the past 30 years by WisDOT. Records from WisDOT Project 0092-02-05, *Performance of Shoulders Adjacent to Concrete Pavements*, will be used as a guide in selecting potential projects (Owusu and Schmitt 2003). A preliminary review of the shoulder study database reveal more than 200 records of

PCC project segments were constructed from 1986 through 2001. To obtain additional project data, the research team will access an integrated database developed during the first stage of WHP Projects 0092-09-30/31, *Implementation of the Mechanistic-Empirical Pavement Design Guide in Wisconsin Phase II*. Meta Manager, Pavement Inventory Files (PIF), and New Construction Report databases were merged by pavement sequence number (ISEQNO) to yield a single composite database for every pavement segment in Wisconsin constructed from 1989 to 2002. The Pavement Research and Management Unit of WisDOT has provided the research team with an updated PIF file that includes 2009 and 2010 distress surveys using PCI measures. These newer PCI-based files will be merged to create a holistic database from which to begin analysis.

A shortcoming of the PIF files for this research is that there is no direct measurement of longitudinal cracking. Longitudinal cracking is measured within the 'Linear Cracking' component of the PCI method, as specified in ASTM D6433-07 (09), *Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys*. 'Linear Cracking' includes any cracks that divide the slab into two or three pieces, usually caused by a combination of repeated traffic loading, thermal gradient curling, and repeated moisture loading (ASTM 2007). There are three primary crack distresses within 'Linear Cracking': longitudinal, transverse, and diagonal. A discussion with the Pavement Research and Management Unit concluded that the current PIF data cannot be segregated for longitudinal cracking, thus, the research team will have to directly measure this distress. First, with the expressed cooperation of the WisDOT Pavement Management Unit, the research team will manually review photo logs of all doweled and non-doweled JPCP sections constructed over the past 25 years in the state. It is very important to review these segments since there may be inherent features within the project causing longitudinal cracks *not* detectable using the current 0.1-mile PIF segment, traditionally extending 0.3 to 0.4 miles from a reference point. In addition, this photo log review will allow an evaluation of pavements in *both* the standard North and East cardinal directions for PIF, and the South and West non-cardinal directions. This review will require added effort, but develop a population of all PCC longitudinal cracking in the state. Electronic photo logs are the least-cost option when compared to driving across each segment. However, the research team has budgeted for travel to PCC segments to verify and visually capture features of the longitudinal cracking not possible with photo logs.

The investigation will focus on Type-8 (doweled JPCP) and Type-5 (non-doweled JPCP) pavement ranging in age from 1 to 25 years. The 25-year cutoff period (about 1986) includes a population of pavement segments having the narrower 12-foot wide panels and the ≥ 14 foot wide panels, allowing for a direct performance comparison.

Although WisDOT has been exclusively designing and constructing doweled JPCP since a 1988 design policy change that only specified Type-8 pavement construction, the research team plans to also investigate Type-5 pavements with dowels. The purpose of both doweled and non-doweled sections is to potentially disclose any factors influencing longitudinal cracking not possible with a doweled-only data set.

Subtask 2.2 - User Survey

For comparison with Wisconsin practices, a preliminary survey has been designed and will be emailed to WisDOT regional offices and Midwestern states having climatic conditions similar to Wisconsin, including Illinois, Iowa, Minnesota, Michigan, Indiana, Ohio. The survey will seek information regarding the policies and procedures used in panel width selection for concrete pavements, condition evaluation methods, common distresses, experience with longitudinal cracking and its probable causes, maintenance treatment practices and costs. To ensure that surveys are returned, phone calls will be made to recipients of surveys. The results from the survey will be analyzed and summarized. A preliminary draft of the survey is provided in Appendix I.

Subtask 2.3 - Pavement Data Evaluation

The objective of subtask 2.3 is to evaluate the field performance of PCC pavements. Longitudinal cracking has been identified as a key distress of interest to WisDOT in this study. As discussed earlier, the longitudinal cracking information (severity and extent) will be extracted from WisDOT photo log files pertaining to distresses and field evaluators' handwritten/scanned documents. Other individual distresses and the composite PCI value itself will also be extracted from the PIF database. Some field verifications will be conducted if photo log displays of longitudinal cracking are difficult to interpret, or warrant further field investigation. Any field distress measurements that will be conducted will be based ASTM D6433-07 (09), *Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys*. The Pavement Management Unit uses a slight variation of the PCI distress measurements in this standard.

There are numerous factors potentially causing longitudinal cracking in PCC pavements. These factors will be clearly grouped, and Table 1 presents a preliminary listing with sample data and considerations. Factors have been subgrouped by design, construction, traffic, and environmental effects.

Task 3 – Data Analysis

The data analysis will be conducted in three subtasks. The first subtask will involve the analysis of the survey data from the Wisconsin regions and other Midwestern states. The second and third subtasks will involve the analysis of the field performance and costs, respectively for the various panel widths in Wisconsin.

Subtask 3.1 - Analysis of Survey data from Midwestern States

Survey data from Wisconsin and other Midwestern states will be analyzed and summarized by state under the following categories:

- a) Criteria for selecting panel width for PCC pavements;
- b) PCC condition evaluation method;
- c) Experience with PCC longitudinal cracking and underlying causes;
- d) Methods to alleviate longitudinal cracking;
- e) Construction methods used;
- f) Maintenance practices and conditions for use; and
- g) Annual maintenance costs for sample projects.

Subtask 3.2 Performance Analysis of Pavements

The sampling design and availability of data described earlier largely drives how a statistically-valid analysis and model development can proceed. This study will critically evaluate measurable factors thought to cause longitudinal cracking on a section-by-section basis. The modeling process will consist of two phases: a preliminary investigative phase and a model-building phase.

The preliminary phase will use basic statistics, scatter plots, and correlations to identify key input factors having an effect on longitudinal cracking. This phase includes necessary data stratification, investigative plots, and cross-classification of variables.

The latter phase includes advance modeling techniques to develop performance models, which can be used to determine critical PCI levels for routine and major maintenance interventions to enable a life cycle cost analysis in the next phase. Equation 1 provides a general framework for the statistical analysis of these factors, and ultimately, the objectives of this study.

$$\text{Longitudinal Cracking} = \text{Design} + \text{Construction} + \text{Traffic} + \text{Environment} + \text{Interactive Effects} + \text{Unexplained Variability (or Error)} \quad (1)$$

Table 1. Potential Factors Causing Longitudinal Cracking

Potential Factor (1)	Measures (2)	Considerations (3)
(a) Design		
Lane Width	12, 13, 14, and 15 feet	Variable width slabs within a project provide a unique opportunity for assignable cause by blocking other effects.
Thickness	8, 9, 10, 11, 12 inches	Ratio of slab width to thickness is critical; accepted industry standard of spacing not to exceed twice the thickness.
Transverse joint spacing	12, 15, 18, 20, variable.	Ratio of joint spacing to thickness also must be limited.
Parting Strips	Yes or No	This factor may have an effect on the ability of the slab to provide contraction relief.
Base thickness	4, 6, 8 inches	Open-graded bases have 8-inch thick base (dense under open).
Dowel bars	Type-5, Type-8	Presence of dowel bars may have an effect, however, this may be partially confounded with pavement age.
Tie bars	Yes, No, Spacing	Bars that tie the adjacent lane or paved PCC shoulder may induce an effect.
Base type	Dense or Open	Drainability allows gravimetric flow of water away from base
Subbase	5 soil regions in state	Clayey, silts, sands, etc., may have an effect.
Subgrade modulus	175, 225, 275 ksi	Subgrade strength is critical in pavement design.
Cross-slope	Tangent, Super-elevated curves	Slope of the pavement (negative or positive) from the centerline can be evaluated.
Gradient	0%, 3%, 5%	Cracking may be more prevalent on one gradient more than the others.
Shoulders	Paved, Unpaved	Tied PCC or HMA, and thickness.
Shoulder sealant	Yes, No	Sealant applied during or after construction.
(b) Construction		
Mixture Design	Flexural strength, fly ash % replacement, etc.	Numerous mix design parameters may have an effect on cracking. This data is valuable, however, difficult to collect.
Dowel bar installation	Basket or Dowel Bar Inserter (DBI)	Installation may have a systematic effect.
Aggregate source	Limestone, gravel, granite, basalt	Absorption, angularity, shear bond with cement paste, presence of chert, etc.
Vibration	VPM, spacing	Slipform paving process has numerous factors affecting the final section. This data is difficult to collect.
Pavement structures	Manholes, loops, culverts, passes, bridges, crossings.	Underlying structures having settlement of fill and subsidence. Overhead structures (bridges) where there may have been inadequate compaction due to jobsite conflicts.
Cut/Fill	Cut or Fill	Fills may produce more longitudinal cracking.
(c) Traffic		
Traffic Volume	AADT, AATT	Total traffic levels and percentage that are trucks.
Lane	Driving, Passing	Distribution percentage.
IRI	110, 140 ipm	Roughness having a relationship with cracking.
(d) Environmental		
Temperature	High and low temperatures	Climates having an effect on thermal expansion/contraction, warping, curling.
Moisture	Inches	Rainfall, snowfall may have an effect.
Age	Years	Life of pavement may or may not have a direct effect on cracking.

Longitudinal cracking is treated as the dependent variable, and measured by the severity and extent using the PCI method. Both severity and extent are to be designated independently or as a composite index. Design inputs are very important, and several primary design factors have been noted in Table 1. Construction is a key factor in the performance of any pavement; however, full construction records for these sections are not readily available. New Construction Report files have many as-built properties, but lack important measures for the concrete mixture and design (specific materials, strength, etc.). Traffic data are readily available in the Meta Manager database. Environmental data are also readily available. If the ANOVA results indicate that panel width is a factor on performance, it is expected that it will be captured in the overall model that will be proposed.

Statistical models are to be developed to quantify the key relationship between longitudinal cracking and all other factors. The primary modeling technique will be Analysis of Variance (ANOVA). The ANOVA procedure first finds the mean of the data, then the function. A key objective is to understand what factors provide a change in the mean longitudinal cracking extent and severity. The ANOVA procedure has the ability to test the significance of a variable when entered last into the model using Type III Sum of Squares, while regression computes the Sum of Squares in the specified model order using Type II Sum of Squares.

An example of longitudinal cracking is shown in Figure 1, in the eastbound driving lane of USH 151 at CTH A overhead bridge southwest of Mineral Point. This pavement segment (ISEQNO 124710) is 10-inch thick doweled pavement placed in 2002, 14-foot wide driving lane, 15-foot transverse unsealed joints, dense-graded base, and both left and right asphalt shoulders. Soil classification is 'Dubuque', section is located in a cut, no culverts or pavement structures, and cracking extends 200 feet both sides of the bridge in the driving lane only. This combination of variables would be incorporated into the database to statistically determine which factor may be the cause. In addition to the statistical modeling, a visual assessment may conclude that construction may have been a potential cause, in particular, base compaction under the bridge.



Figure 1. Longitudinal Cracking in Eastbound USH 151 at CTH A south of Mineral Point (February 9, 2011)

Subtask 3.3 Analysis of Costs

The cost analysis will initially involve the identification of (a) comparable sections for the same PCC type, (b) the stage or time in pavement life when maintenance and rehabilitation activities were performed, and (c) cost elements to include in a life-cycle cost analysis (LCCA) for the comparable sections. Sections will be considered “comparable” if they have different panel widths but the same travel lane structural capacity and have similar characteristics such as functional classification or traffic loads, design subgrade condition, and regional location.

The timing for the application of specific maintenance and rehabilitation activities has a profound impact on the outcome of any LCCA. A one-year change in rehabilitation in a forward or backward direction can alter the life-cycle cost (LCC) results. Initial estimates will be made using inputs from the survey data (Subtask 2.2) and/or model estimates developed under Subtask 3.2. Oftentimes maintenance intervention is delayed due to funding constraints. If any such situation arises, its impact on the LCCA will be examined through the use of a sensitivity analysis technique.

The type of pavement selected for a highway improvement project generally results from the analysis of economic and engineering factors. The ultimate goal is to determine the minimum LCC for some prescribed service levels over a given period of analysis. The cost elements considered in the LCC for pavement improvement projects include: Agency costs (from construction, maintenance and operation, rehabilitation, and salvage value), and road user costs (from new construction or rehabilitation time delays, fuel consumption, driver discomfort, accidents, vehicle wear, etc.). User costs are rarely used by majority of states (including WisDOT) in LCCA for pavement structures; the reason is that the costs are not recoupable and data accuracy is also questionable. Agencies using user costs tend to focus on time delays but it is not clear from the literature whether they use it to compare pavement design alternatives. In this analysis, only agency costs will be considered. If the survey data, however, indicate the availability of any user cost component (e.g., time delays from construction and/or rehabilitation operations), then it will be considered in the LCCA. Additional data that would be required in the LCCA include the analysis period and the discount rate. The values prescribed by WisDOT for pavement structures will be utilized (i.e. a 5% discount rate and a 50-year analysis period).

There is a great amount of uncertainty associated with various input parameters for LCCA. Construction costs are generally easy to obtain and can be predicted with a high degree of certainty for an analysis because of up-to-date bid prices. Future maintenance costs, on the other hand, may not be very accurate because of variations in pavement performance and the general lack of good reliable maintenance cost data. Where maintenance cost data are available, most often they are not definitive. That is, maintenance costs may cover a very long road section and cannot be broken out for short sections or for variations in pavement performance within the longer road section. The length of time until maintenance or rehabilitation might be required as well as the extent necessary to restore the pavement at that time also has a relatively high degree of uncertainty attached. Hence a sensitivity analysis will be performed to determine the relative effects of variations in the maintenance treatment lives and costs associated with the various PCC options on the outputs from the LCCA. Such an analysis is particularly beneficial when the difference between alternatives may not be too large. It will also eventually help in defining a band of PCI or longitudinal cracking distress magnitudes over which maintenance will be cost effective for a particular PCC type and cross section.

Task 4 – Development of Guidelines

The objective of Task 4 is to develop guidelines to address the following items for PCC pavements:

- Criteria for panel width. The criteria guide may take the form as shown in Table 2. Each cell will contain a brief description of the significant factors for selecting a specific PCC panel width on the basis of the functional class.

Table 2. Criteria for Selecting JPCP Panel Width

Highway Class	PCC Panel Width (feet) by Pavement Thickness			
	$t \geq 8''$	$t \geq 9''$	$t \geq 10''$	$t \geq 11''$
4-lane Rural	A	A	A	A
2-lane Rural	A	A	A	A
Other	A	A	A	A
^A To be determined from statistical models and life-cycle cost analysis.				

- Performance guide for maintenance intervention. The guide will consist of either a simplified performance matrix or a series of model equations for determining the distress or PCI threshold levels for maintenance intervention.
- Maintenance practices and costs guide. The common maintenance practices and corresponding annual unit costs for PCC will also be presented. A life cycle cost analysis summary of the different PCC types and cross-sections will be included to aid WisDOT in the design process.

Task 5 - Final Report

The results of all tasks will be documented in a final report and submitted for 3-month review.

Anticipated Research Results and Implementation Plan

The anticipated results of this research include:

- Provision of a rational method for selecting a particular cross-section design for concrete pavements;
- Development of a framework for evaluating the performance and cost effectiveness of concrete pavement cross-section alternatives; and
- Expansion of WisDOT's database to include condition data for concrete pavements selected for field verification in this research.

It is anticipated that the research will be ready for implementation at the conclusion of the study. Guidelines will be prepared to assist WisDOT and provide the necessary details for implementing the findings of the research. The guidelines will include:

- Procedures for selecting concrete pavement cross-sections for various highway classes;
- Performance guide for maintenance intervention for the various cross-sections on the basis of their anticipated performance; and
- Cost guide for concrete pavement practices in Wisconsin.

A final implementation manual will most likely be the responsibility of WisDOT, using their publication formats and technical input from necessary committee work.

5. Time Requirements

The research described in this proposal will require a duration of 18 months. Figure 2 presents a schedule showing the start of each work task. The work plan will be executed in a timely manner after

August 1, 2011, to meet the 18-month project duration. Data collection for the work plan can occur throughout the year, with snow cover as the only restriction. Analysis of the data will occur as they become available.

Task	Description	2011					2012												2013
		Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
1	Lit. Review & User Survey																		
2	Experimental Plan																		
3	Data Analysis																		
4	Develop Guidelines																		
5	Final Report																		

Figure 2. Project Schedule

6. Budget

The research study will be staffed by Dr. Samuel Owusu-Ababio, Dr. Robert Schmitt, and two senior-level civil engineering students at the University of Wisconsin-Platteville. The total estimated cost for the project is \$50,000. This estimate is based on a projected start date of August 1, 2011 and a completion date of January 31, 2013. A breakdown of the budget components by work task is provided in Table 3, while Table 4 shows the expected total hours by task that to be committed to complete the project

Table 3: Estimated Task Cost

INDIVIDUALS	TASKS					TOTAL	Fringes	Total Direct
	1	2	3	4	5			
Principal Investigator	1898	3321	3321	1423	1898	11861	6962	18823
Co-Principal Investigator	1308	3052	3052	1308	1744	10464	6141	16605
Hourly Students/Junior Staff	300	3540	360	0	0	4200	113	4313
Office Staff	0	0	0	0	0	0	0	0
TOTALS	3506	9913	6733	2731	3642	26525	13216	39741
Total Contract Summary by Federal Fiscal Year								
	1	2	3	4	5	Fiscal Year 1	Fiscal Year 2	TOTAL
Total Salaries and Wages	3506	9913	6733	2731	3642	20152	6373	26525
Other Direct Costs	1890	3836	3750	1603	2138	9476	3741	13217
Materials & Supplies	0	0	688	0	0	688	0	688
Printing	0	0	0	0	100	0	100	100
Communications (CDs, Re	50	50	0	0	0	100	0	100
Travel	0	2322	100	0	53	2422	53	2475
Sub-Contracting (Database	0	0	0	0	0	0	0	0
TOTAL DIRECT COSTS	5446	16121	11271	4334	5933	32838	10267	43105
Indirect Costs	879	2579	1789	693	955	5247	1648	6895
Overhead	0	0	0	0	0	0	0	0
TOTAL INDIRECT COSTS	879	2579	1789	693	955	5247	1648	6895
TOTAL CONTRACT COST	6325	18700	13060	5027	6888	38085	11915	50000

Table 4. Summary of Hours

INDIVIDUALS	TASKS					TOTAL HOURS
	1	2	3	4	5	
Principal Investigator	40	70	70	30	40	250
Co-Principal Investigator	30	70	70	30	40	240
Hourly Students/Junior Staff	25	295	30	0	0	350
TOTALS	95	435	170	60	80	840

7. Qualifications of Research Team

The research team members are provided in Table 5.

Table 5. Research Team

Name (1)	Research Position (2)	Address/Phone/Email (3)
Sam Owusu-Ababio, P.E., Ph.D. Professor UW-Platteville	Principal Investigator	1 University Plaza Platteville, WI 53818 (608) 342-1554 (608) 342-1566 fax owusu@uwplatt.edu
Robert L. Schmitt, P.E., Ph.D. Professor UW-Platteville	Co-Principal Investigator	1 University Plaza Platteville, WI 53818 (608) 342-1239 (608) 342-1566 fax schmitro@uwplatt.edu
Two UW-Platteville Civil Engineering seniors	Research Assistants	UW-Platteville, College of Engineering, Mathematics, and Science

Sam Owusu-Ababio

Dr. Sam Owusu-Ababio is a Professor of Civil Engineering at the University of Wisconsin Platteville where he has taught courses in pavement analysis and design, highway engineering, and transportation engineering for the past 18 years. He is a registered professional engineer in Wisconsin.

Dr. Sam Owusu-Ababio has over the years worked on a number of WisDOT projects. He served as the Principal Investigator for WHRP Studies, *Performance of Paved Shoulders Adjacent to Mainline Concrete Pavements*, and *Effects of Heavy Loading on Wisconsin's Concrete Pavements*. He was Co-Principal Investigator for recently completed WHRP Project *Performance Evaluation of Open Graded Base Course with Doweled and Non-doweled Transverse Joints on USH 18/151, STH 29, and USH 151*.

Prior to teaching at UW-Platteville Dr. Owusu-Ababio worked with the pavement research unit of the Connecticut Department of Transportation (ConnDOT) where he conducted research on long-term pavement performance. While working for ConnDOT, he also served as a pavement management consultant to the Pioneer Valley Planning Commission (a metropolitan planning agency responsible for 46 cities and towns) in Springfield, MA.

Dr. Owusu-Ababio's current research interests are in the areas of pavement performance, pavement design and management, and application of statistical methods and neural computing to pavement engineering. He has published more than 30 papers in national and international journals and conference proceedings and has given formal presentations at national and international transportation related conferences.

Robert L. Schmitt

Dr. Robert Schmitt is a Professor of Civil and Environmental Engineering at the University of Wisconsin – Platteville. Dr. Schmitt has 25 years of combined industry and research experience and has participated in numerous transportation-related research projects sponsored by the Federal Highway Administration, WisDOT, WHP, and NCHRP. He was a Co-PI for a 2001-2003 WHP Study, *Performance of Paved Shoulders Adjacent to Mainline Concrete Pavements*, and *Effects of Heavy Loading on Wisconsin's Concrete Pavements*. He was Principal Investigator for recently completed WHP Project *Performance Evaluation of Open Graded Base Course with Doweled and Non-doweled Transverse Joints on USH 18/151, STH 29, and USH 151*.

He has published 28 papers related to highway pavements. He is a registered professional engineer in the State of Wisconsin. Specifically for this project, Dr. Schmitt will assist Dr. Owusu-Ababio in literature review of design standards, synthesize the data, and write the final report.

UW-Platteville Research Assistants

UW-Platteville civil engineering students will participate for the duration of the study. Civil engineering students that have successfully completed the CEE 4560 course, "Pavement Maintenance and Rehabilitation", and the Math 4030 course, "Statistical Methods with Applications", will be given priority to work with the research team. The CEE 4560 course teaches (1) evaluation of pavement distresses, (2) maintenance techniques used for their repair, (3) survey and evaluation methods, maintenance equipment and procedures, rehabilitation techniques, and identification of cost-effective options, and (4) maintenance management software to evaluate options. The Math 4030 course teaches probability, distribution functions, special discrete and continuous distributions, hypothesis testing, chi-square, correlation and regression. Two civil engineering students will be assigned to literature review and synthesis of current practices, review photo logs, and participate in verification of field data .

8. Other Commitments of the Research Team

Drs. Schmitt and Owusu-Ababio have nine-month appointments in the Civil and Environmental Engineering Department at UW–Platteville. During this nine-month appointment, they teach courses and advise students. It is estimated that they will be able to dedicate a considerable amount of time to complete the project within the 18-month period proposed by the WHP. The research team's commitment for this project is as outlined in Table 6.

Table 6: Commitments of Research Team

Research Team Commitments		Percentage of Time	
Team Member	Role	Committed	Available
Samuel Owusu-Ababio	PI	75%	25%
Robert Schmitt	Co-PI	75%	25%
Undergraduate Students	Research Assistants	75%	25%

9. Facilities and Information Services

The University of Wisconsin – Platteville has the available facilities to fulfill the research requirements. Office space, computers, and vehicles for data collection are the primary resources necessary to conduct the research. The university has computers and a wide variety of software for data management. It is anticipated, however, that new, more-efficient software will be purchased to assist with data analysis.

10. Technical Certifications

Technical certifications are not required for this project.

References

Ardani, A., Hussain, S., and LaForce R. (2003). "Evaluation of Premature PCCP Longitudinal Cracking in Colorado", Colorado Dept. of Transportation Research Branch, Report No. CDOT-DTD-R-2003-1, Denver, CO., 2003.

ASTM (2007). "Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys", D6433-07(09), West Conshohocken, PA.

Federal Highway Administration (2003). "Distress Identification Manual for the Long-Term Pavement Performance Project", FHWA, Washington, D.C. 2003.

Janda, H F. (1935). "Longitudinal Cracking of Concrete Pavements on State Highways 13 in Clark and Taylor Counties, Wisconsin", Transportation Research Board,
<<http://pubsindex.trb.org/view.aspx?id=105072>>, (Feb. 23, 2011).

Ohio Department of Transportation (2011). "Summary of Findings Concerning Longitudinal Cracking on 16' Wide Ramps", Office of Pavement Engineering, Columbus, OH,
<http://www.dot.state.oh.us/Divisions/HighwayOps/Pavement/Additional%20Information/Longitudinal_Joints_on_Ramps.pdf>, (Feb. 23, 2011).

Appendix I. Sample Survey

DRAFT SURVEY QUESTIONNAIRE ON JOINTED PLAIN CONCRETE PAVEMENT PANELS

Dear Sir/Madam:

The Wisconsin Department of Transportation (WisDOT) is currently involved in a joint research project with the University of Wisconsin-Platteville aimed at developing guidelines for the selection of panel widths for Jointed Plain Concrete Pavements (JPCP) to minimize longitudinal cracking and improve JPCP performance. The research team will be very grateful if you could complete the attached survey questionnaire and return it to the address below. The success of this study in part depends upon your input. Upon completion of the study, an email link of the final report will be sent to you.

Name of Organization: _____

Address: _____
City: _____ State: _____ Zip: _____

Questionnaire completed by: _____

Position /Title: _____

Telephone: _____

Fax: _____

e-mail _____

RETURN QUESTIONNAIRE AND SUPPORTING DOCUMENTS BY October 15, 2011

Dr. Sam Owusu-Ababio, P.E.
University of Wisconsin - Platteville
Dept. of Civil & Environmental Engineering
136 Ottensman Hall
Platteville, WI 53818

For questions contact him by phone: 608-342-1554; fax: 608-342-1566; e-mail: owusu@uwplatt.edu

1. What criteria does your agency use in selecting panel widths for mainline Jointed Plain Concrete Pavements? **Mark all that apply.**

☐ Highway Functional Class
☐ Traffic Volume
☐ Truck Traffic
☐ Ease of Construction
☐ Construction & Maintenance cost
☐ Experience & judgment
☐ Pavement Thickness
☐ Other (please specify_____)

Please supply copies of memoranda, policies, or guidelines pertaining to the criteria you have marked above.

2. What are the standard JPCP panel widths used by your agency/region on *rural 2-lane* highways? Mark all that apply

☐ 12ft ☐ 13ft ☐ 14ft ☐ 15ft ☐ Other (please specify_____)

3. What are the standard JPCP panel widths used by your agency/region on *rural multi-lane* highways? Mark all that apply

☐ 12ft ☐ 13ft ☐ 14ft ☐ 15ft ☐ Other (please specify_____)

Comments:_____

4. What are the primary causes of longitudinal cracking on JPCP pavements under your jurisdiction?

Mark all that apply

☐ Inadequate pavement thickness
☐ Improper construction practice (See question 5)
☐ Differential heaving of subgrade
☐ Wider panels
☐ Other (specify_____)

5. What possible construction related practices might have contributed to longitudinal cracking of JPCP under your jurisdiction? **Mark all that apply.**

☐ Misaligned dowel bars
☐ Inadequate subbase compaction
☐ Timing of saw-cut at longitudinal joints at shoulder and centerline
☐ Saw-cut depth at shoulder and centerline joints
☐ Vibrator trails from faulty vibrators on paver
☐ Other (specify_____)

6. What are the locations for the longitudinal cracks that tend to appear in the JPC pavements under your jurisdiction? Mark all that apply.

___ Center of slab

___ Edge of slab

___ Approximately ___ feet of the sawed longitudinal joint

___ Other (specify _____)

7. What methods does your agency use to correct longitudinal cracking that appear prematurely in JPC pavements under your jurisdiction?

Please supply copies or internet sites of memoranda, policies, or guidelines pertaining to the methods

8. For the JPC that experienced premature longitudinal cracking, how many months or years elapsed before the first appearance of the cracks?

9. What methods does your agency use to correct longitudinal cracking that **do not** occur prematurely (i.e. expected normal cracks)?

10. For the methods outlined in question 7 and/or 8, please supply cost information for the treatment of the longitudinal cracking.